

TeraHz Limb Sounder (TLS) for Lower Thermosphere Wind, Temperature, and Atomic Oxygen Density Sensing: System Design and Performance Demonstration

Completed Technology Project (2016 - 2019)



Project Introduction

We demonstrate the performance of a compact high resolution heterodyne spectrometer operating at Terahertz (THz) frequencies to provide global lower thermospheric neutral winds, temperature and density measurements from a low-earth orbit platform. These critical measurements are needed to better understand underlying mechanisms of the upper atmospheric composition/dynamics/temperature variability and the role of neutral dynamics on the ionospheric variability. Yet, no satellite remote sensing technique provides neutral wind measurements in the 100-150 km altitude region with the full diurnal coverage, spatial resolution, precision and accuracy required for comprehensive coupling process studies. As a result, the data gap in this transition region leaves a number of fundamental questions unanswered about the lower thermosphere, especially those related to how the upper atmospheric plasma state is coupled to the neutral dynamics below. Solar and Space Physics: A Science for a Technical Society, authored by the National Research Council Committee on a Decadal Strategy for Solar and Space Physics (Heliophysics) in 2012 (HDS) established a goal to understand how the neutral atmosphere and plasma are coupled and stressed that accurate measurements of neutral temperature and winds in the lower thermosphere are crucial for understanding ionospheric variability. The THz Limb Sounder (TLS) instrument, to be developed and demonstrated under this proposed Heliophysics Technology and Instrument Development for Science Program (HTIDS) investigation, can, for the first time, measure global neutral wind profiles during both day and night at 100-150 km where most of the ion-neutral energy/momentum coupling takes place. The TLS instrument resolves the Doppler line shape of atomic oxygen emission at 2.06 THz (145 μm) and provides simultaneous wind, temperature and atomic oxygen density measurements in the region. Together these measurements provide critical observational constraints to the complex dynamics in the coupled lower atmosphere/thermosphere/ionosphere system, as highlighted in the 2012 HDS and 2014 Heliophysics Science and Technology Roadmap for 2014-2033. This HTIDS instrument unequivocally supports the science objectives of DYNAMIC (Dynamical Atmosphere Ionosphere Coupling), a 2014 Roadmap recommended a Solar Terrestrial Probes (STP) mission, which directly benefits future Heliophysics mission planning and implementation. In addition, TLS is compact, small, light-weight, low power and ideal to support future cost-effective science missions in implementing the Decadal Survey DRIVE (Diversify Realize, Integrate, Venture, Educate) initiative. The TLS instrument development and performance demonstration effort is a joint project between The Johns Hopkins University, Applied Physics Laboratory (JHU/APL), The NASA Jet Propulsion Laboratory (JPL) and Goddard Space Flight Center (GSFC). Scientific payloads on future NASA Heliophysics missions, including DYNAMIC, is likely resource-limited and cost-constrained. Under the proposed 36-month HTIDS project (3/1/16 to 2/28/19), we will develop and optimize a compact, low-mass, and low-noise THz receiver concept to meet both



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Heliophysics science and programmatic requirements. We will design, build and integrate a single-element TLS receiver system at 2.06 THz with the sensitivity and stability required for E-region wind measurements. This THz receiver system will be operated at 120-150 K ambient temperature, which is achievable with passive radiators in space. This HTIDS project, allows focus on the THz receiver system integration, optimization and demonstration of two key subsystems developed under our currently funded efforts: (1) high-yield local oscillator chain and (2) low-noise THz mixer. The successful completion of the proposed HTIDS project will not only reduce implementation risk/cost for future Heliophysics missions, but also shorten instrument development time.

Anticipated Benefits

Support NASA's strategic objectives to understand the Sun and its interactions with Earth and the solar system, including space weather. This will be achieved by developing/demonstrating instrumentation technology necessary to address the following science goals:

- Explore the physical processes in the space environment from the Sun to the Earth and throughout the solar system;
- Advance our understanding of the connections that link the Sun, the Earth, planetary space environments, and the outer reaches of our solar system;
- Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Johns Hopkins University

Responsible Program:

Heliophysics Technology and Instrument Development for Science

Project Management

Program Director:

Roshanak Hakimzadeh

Program Manager:

Roshanak Hakimzadeh

Principal Investigator:

Jeng-hwa Yee

Co-Investigators:

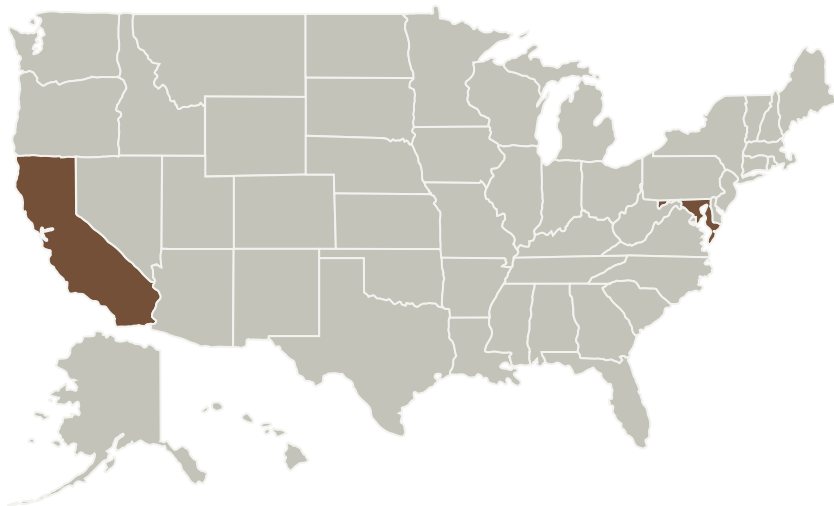
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Primary U.S. Work Locations and Key Partners

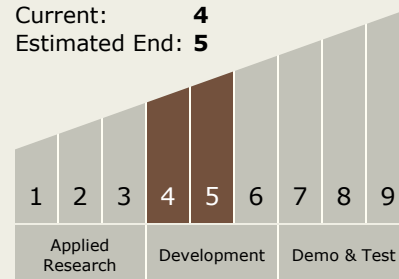


Organizations Performing Work	Role	Type	Location
Johns Hopkins University	Lead Organization	Academia	Baltimore, Maryland

Primary U.S. Work Locations	
California	Maryland

Technology Maturity (TRL)

Start: **4**
Current: **4**
Estimated End: **5**



Technology Areas

Primary:

- TX08 Sensors and Instruments
 - TX08.1 Remote Sensing Instruments/Sensors
 - TX08.1.4 Microwave, Millimeter-, and Submillimeter-Waves

Target Destination

The Sun